SCHOHARIE DEVELOPMENT OF THE CATSKILL WATER SUPPLY SYSTEM FOR NEW YORK CITY

By J. Waldo Smith

With the award of the Gilboa dam contract on June 23, 1919, of the highway contract on June 13, 1919, of the Shandaken tunnel contract on November 9, 1917, and with the acquisition of title to the necessary property in 1917, construction activities on the Schoharie development are well under way. The Schoharie source, which is adjacent to and immediately north of the Esopus, will furnish the necessary water, 250,000,000 gallons a day, supplementing the 250,000,000 gallons from the Esopus source already reaching the city, to supply 500,000,000 gallons a day which the Catskill aqueduct will carry. The construction progress required by the contracts is such as to complete the work by the end of 1924. The estimated cost of the project is $22,175,400. Thus the Catskill system will be extended 36 miles north from the Ashokan dam, making an overall distance for the system of 156 miles from the new dam to the terminal reservoir on Staten Island.

The original Catskill plan. The original comprehensive plan prepared by the Board of Water Supply and adopted by the Board of Estimate and Apportionment in 1905 provided for the building of structures sufficient to gather, filter and convey to the city not less than 500,000,000 gallons daily of water from the Catskill Mountain sources. These sources were Esopus, Rondout, Schoharie and Catskill creeks, which it was estimated could yield 250,000,000, 125,000,000, 136,000,000, and 149,000,000 gallons a day respectively, aggregating together 660,000,000 gallons a day from which the 500,000,000 gallons a day of Catskill Mountain water would be obtained.

First development. The first stage has been completed and in operation since 1917. This included the construction of the Ashokan reservoir, developing Esopus creek to furnish 250,000,000 gallons a day, and the Catskill aqueduct and appurtenances with a carrying capacity of not less than 500,000,000 gallons a day. The Ashokan

Statistics of Ashokan, Kensico and Schoharie Reservoirs

	ASHOKAN STORAGE RESERVOIR	SCHOHARIE STORAGE RESERVOIR	KENSICO EMERGENCY RESERVOIR
Capacity, total	130,000,000,000 gallons	22,000,000,000 gallons	38,000,000,000 gallons
Capacity, available	128,000,000,000 gallons	20,000,000,000 gallons	29,000,000,000 gallons
Water surface	12.8 sq. miles = 8,180 acres	1.83 sq. miles = 1,170 acres	3.5 sq. miles = 2,218 acres
Land, acquired	23.8 sq. miles = 15,222 acres	3.72 sq. miles = 2,372 acres	7.0 sq. miles = 4,500 acres
Elevation of top of dam, above tide	610 feet	1,130 feet	370 feet
Length of reservoir	12 miles	5 miles	4 miles
Length of shore line	40 miles	12 miles	30 miles
Length of dams and dikes	5½ miles	2,300 feet	3,300 feet
Main dam:			
Total length	4,650 feet	2,300 feet	1,825 feet
Length of masonry portion	1,000 feet	1,300 feet (Earth, 1,000 feet)	1,825 feet
Height (maximum)	252 feet	160 feet	307 feet
Thickness at base (maximum)	190 feet	165 feet	235 feet
Thickness at top (minimum)	23 feet	15 feet	28 feet
Width of reservoir:			
Maximum	3 miles	4/5 mile	3 miles
Average	1 mile	2/5 mile	1 mile
Depth of reservoir:			
Maximum	190 feet	140 feet	155 feet
Average	50 feet	58 feet	52 feet
Villages submerged	7	1	1
Permanent population of submerged area at beginning of work	2,000	350	500

Cemeteries removed	32	7	None
Bodies reinterred	2,800	1,330	None
Railroad relocated	11 miles	None	None
Highways discontinued	64 miles	13.6 miles	14.8 miles
Highways built	40 miles	12.4 miles	15.1 miles
Highway bridges built	10	2	4
Earth and rock excavation	2,500,000 cubic yards	488,500 cubic yards	1,400,000 cubic yards
Embankment	7,300,000 cubic yards	617,000 cubic yards	2,010,000 cubic yards
Masonry	900,000 cubic yards	436,000 cubic yards	965,000 cubic yards
Cement	1,200,000 barrels	480,000 barrels	897,000 barrels
Maximum number of men employed	3,000		1,500

reservoir, however, was constructed of the largest practicable size, 128,000,000,000 gallons available storage, in order to care not only for the requirements of storage for the Esopus, but also to provide storage, something like 45,000,000,000 gallons as it was worked out theoretically, for the Schoharie or Catskill creeks.

The storage of water began in Ashokan reservoir when the opening through the dam was closed on September 9, 1913; the first filling of Kensico reservoir began on November 22, 1915, three years ahead of contract time; Catskill water was delivered to Bronx borough December 27, 1915, to Manhattan borough November 29, 1916, and to all boroughs, including Brooklyn, Queens and Richmond, on January 22, 1917, and continuously thereafter.

Authority to develop Schoharie. In 1906, in approving the city's petition for permission to take water from the Catskill watersheds in accordance with the comprehensive plan, approval as to the Schoharie was denied because of a legal technicality. Meanwhile, during the construction period of the first stage in 1907, 1912 and 1914, the petition to the State Water Supply Commission and its successor, the State Conservation Commission, to take the waters of Schoharie creek was renewed, being approved in 1914. With this approval came the time when the city was at liberty to plan for the development of any or all of the sources in the original plan as should prove necessary to complete the supply of 500,000,000 gallons a day.

Rondout source abandoned. Subsurface investigations of dam sites were carried on intermittently, though fairly constantly, since 1907 in the Rondout and Schoharie valleys. Many locations for a dam site were investigated on the Rondout, which is contiguous to the aqueduct on the west, but none was found which the engineers could recommend. The pre-glacial gorge was found to be very deep and to one side of the present stream bed. There was an over burden of glacial drift, then a bed of clay was penetrated, after passing through which in many places the casings used in the boring work would sink many feet of their own weight or with very little resistance through a superfine sand or quicksand, and accompanied in most instances by continuous artesian flow of water under pressure. These conditions, found to be general in that section of the valley available to the project, would increase the cost of construction of a dam beyond reasonable amounts, even if practicable methods of construction could be devised. One flowing boring proved to be a

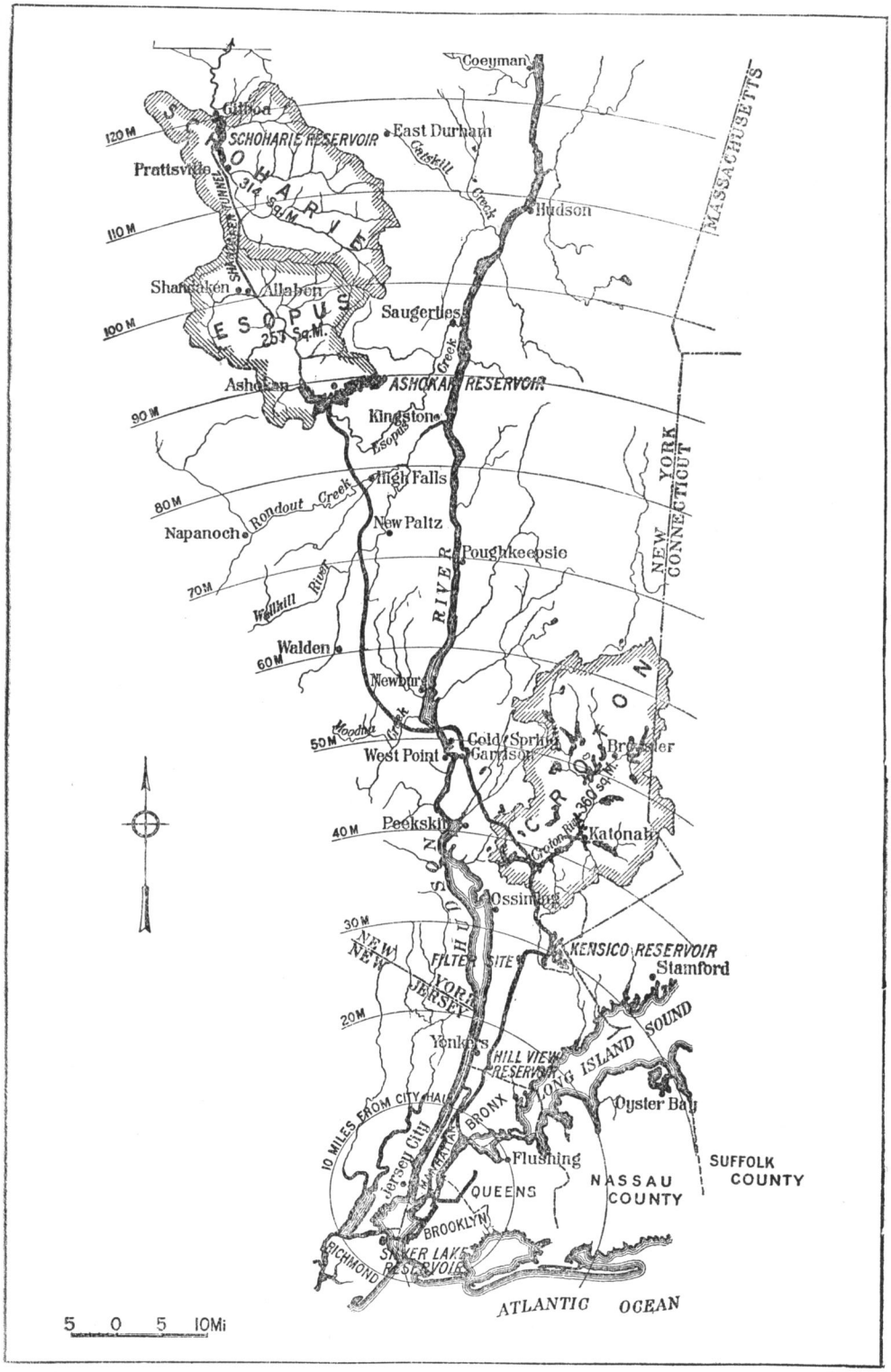


FIG. 1. MAP OF THE CATSKILL WATER SYSTEM FOR THE CITY OF NEW YORK

very persistent producer. The ordinary methods of plugging it were unavailing. Many carloads of cement were injected as grout in an attempt to seal the clay bed penetrated, without permanent success; if stopped in one place it would break out nearby. This flowing water carried considerable turbidity and a crater of appreciable size was formed. Finally the city purchased a few acres about it and filled in the crater each year for three or four years with one-man stones and gravel, with the idea of forming a natural rock spring, thereby clarifying the discharge. With this method of treatment the flow has now ceased.

On account of the unfavorable physical conditions and consequent greatly increased cost of developing the Rondout, the original plan of going there for the second source and to the Schoharie or Catskill for the third source had to be reconsidered, with the result that the Rondout was finally abandoned.

Catskill source early set aside. Extensive detailed investigations were never made of dam sites on Catskill creek, which lies to the northeast of Ashokan reservoir on the easterly slopes of the mountains. The 32½ mile aqueduct, eight reservoirs on five streams, the low rainfall of 34.66 inches per annum combined with low run-off reducing the early estimated safe yield from 149,000,000 gallons a day to 120,000,000 gallons, altogether formed such a combination of unfavorable factors, disclosed early in the investigations, as to cause Catskill creek to be considered as an alternative source for possible future use. A preliminary estimate of cost for developing this source was $41,880,000.

Schoharie source with dam at Prattsville. The sub-surface investigation in the Schoharie valley indicated a satisfactory dam site at the original location, the village of Prattsville, where the contemplated reservoir would have had a flow line at elevation 1240 feet above sea level and a storage capacity of 9,500,000,000 gallons. From the Prattsville reservoir the tunnel to the Esopus valley would have been 10 miles long. The accurate records of stream flow disclosed that the Schoharie has a higher yield than previously had been estimated. The rainfall is very close to that originally estimated, but the percentage of it appearing as stream flow is much higher, so that the yield compares favorably with the Esopus. Of the 47 inches depth of rainfall in a year on the Esopus watershed, 29.5 inches (63 per cent) appears as stream flow, while the Schoharie, with only 39.5 inches of rainfall, yields 27.2 inches (69 per cent) as

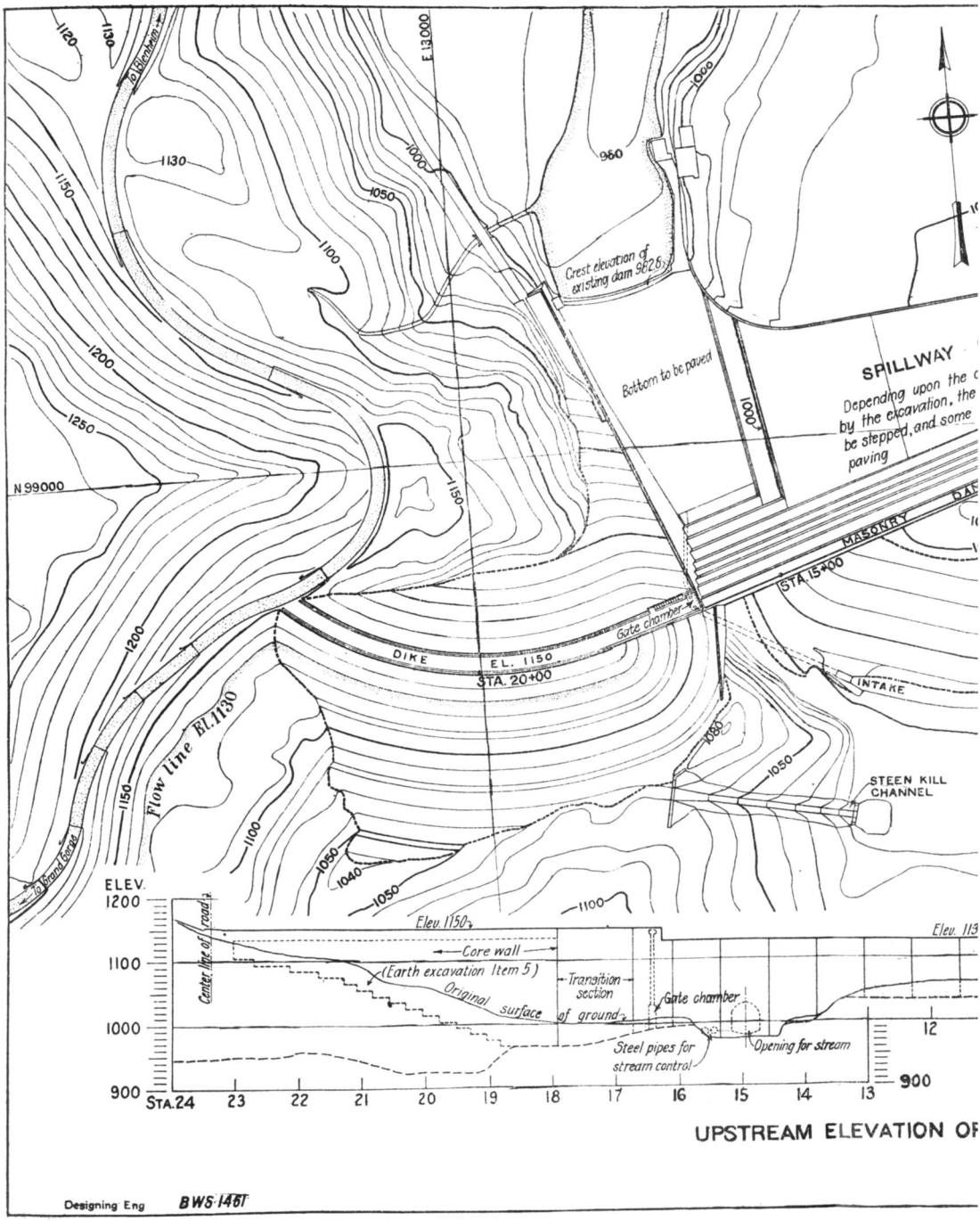
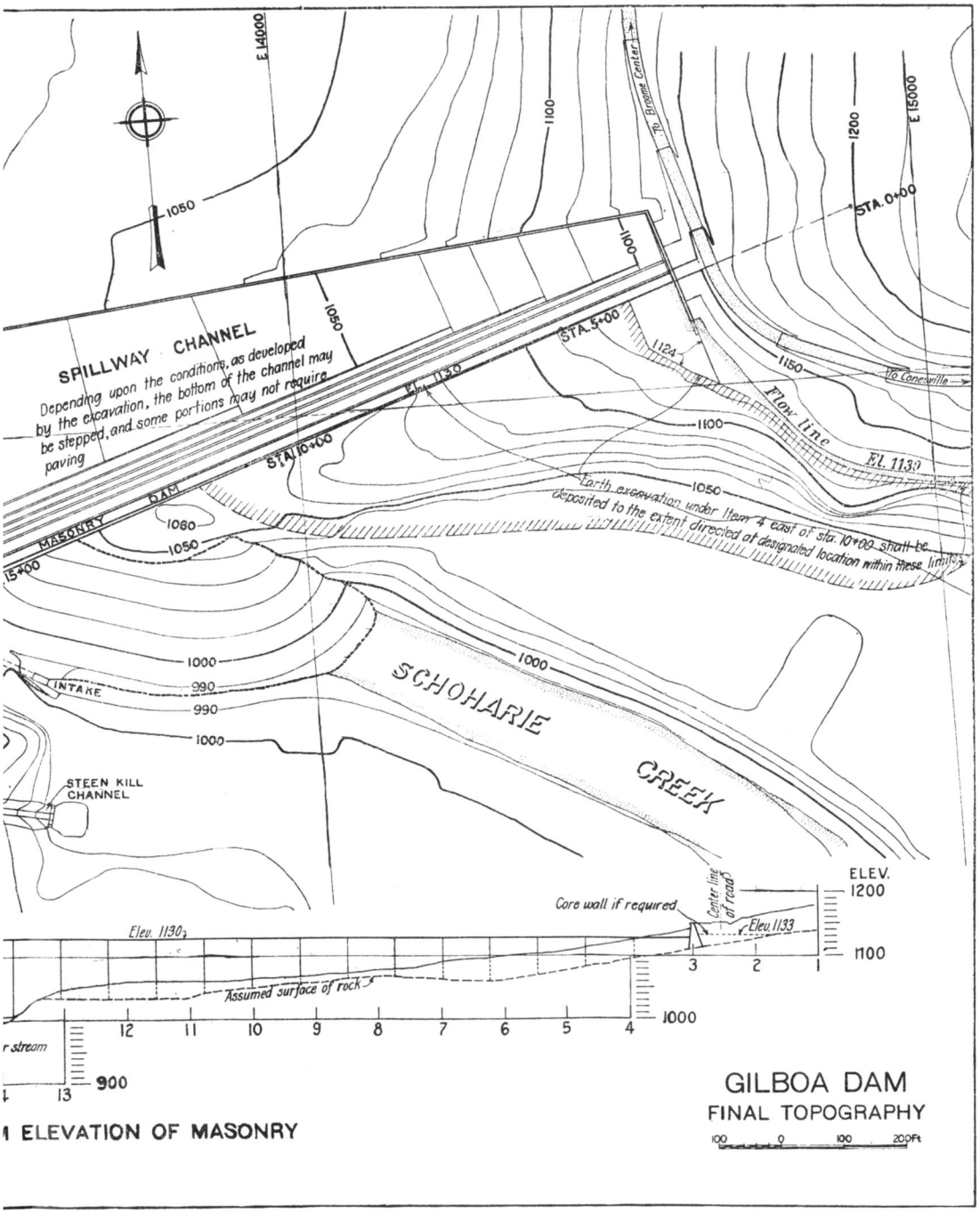


FIG. 2. PLAN OF THE GILBOA DAM AND ELEVAT



. Dam and Elevation of the Masonry Portion

stream flow. Compared with these, the Croton yields 22.4 inches of stream flow, and the Wachusett watershed of the Boston supply yields but 21.3 inches of stream flow on the average.

With these favorable conditions it was found that the estimated safe yield from the 226 square miles of catchment area above Prattsville should be increased from 136,000,000 gallons a day to 200,000,000, leaving therefore, only 50,000,000 gallons a day shortage in the full aqueduct supply. The estimated cost of the Schoharie development with dam at Prattsville was $14,216,000. This plan has been amended as hereinafter outlined.

Schoharie source with dam at Gilboa. Consideration was then given to the possibility of securing 250,000,000 gallons a day from the Schoharie by placing the dam further down stream. Borings, aggregating nearly five miles in depth, were made and the ground between Devasego Falls and Gilboa was well covered by surveys and examinations. The results of these investigations disclosed that the most practicable site for the necessary dam would be at Gilboa. The drainage area above this location is 314 square miles. The dam will be 160 feet high above the stream bed, forming a reservoir with flow line 1130 feet above sea level, containing storage of 22,000,000,000 gallons, of which 20,000,000,000 gallons will be available. This will act as a diverting reservoir as well as a storage reservoir and will be operated in conjunction with the Ashokan by means of the tunnel to Esopus creek. The tunnel will extend 18 miles from about a mid-point on the reservoir, discharging into Esopus creek at Allaben, where the water will mingle with the water of Esopus and follow the natural channel bed of Esopus for 11 miles into Ashokan reservoir. The tunnel will have a capacity of 600,000,000 gallons a day, which is double the average supply to be drawn, the large capacity being necessary to transport the water to Ashokan during times of plenty. The Esopus and Schoharie sources to contribute to the Catskill Mountain Supply have the following features:

RESERVOIR	DRAINAGE AREA	RESERVOIR AREA	AVAILABLE STORAGE	PROBABLE MEAN STREAM FLOW A DAY
	sq. mi.	*sq. mi.*	*gallons*	
Ashokan	257	12.78	128,000,000	361,000,000
Schoharie	314	1.83	20,000,000	406,000,000
Combined	571	14.61	148,000,000	767,000,000
Kensico	22	3.47	29,000,000	18,000,000
Total Catskill System	593	18.08	177,000,000	785,000,000

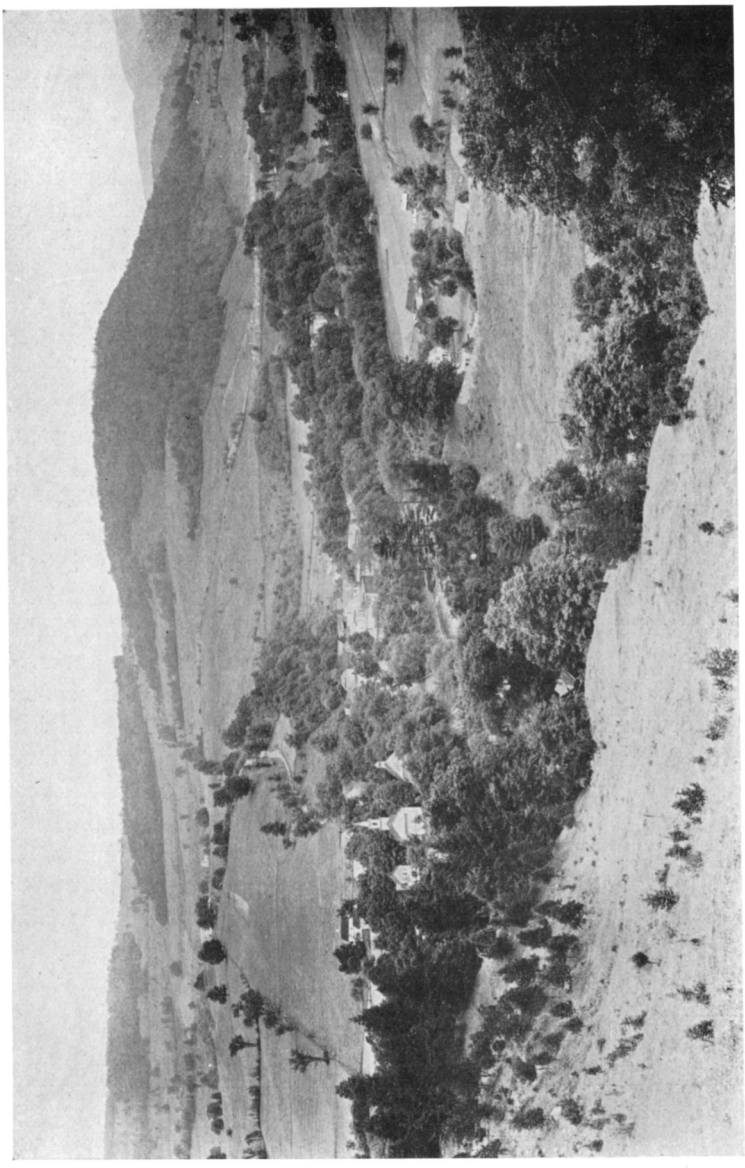


FIG. 3. THE SITE OF THE GILBOA DAM

The studies indicate that during large floods and for short periods there will be some waste at both reservoirs. On the other hand the heavy draft will cause rapid depletion of the reservoirs each year, normally exceeding 60,000,000,000 gallons, and with two or three unfavorable years in succession the depletion may reach 100,000,000,000 gallons.

The estimated cost of the Schoharie development with dam at Gilboa was $22,175,400.

The results of the studies and investigation showed: (1) that the Schoharie watershed is the one most available for completing and rounding out the full Catskill supply of 500,000,000 gallons a day; (2) that the proposed location of the dam at Gilboa removes the uncertainty of the foundation problem encountered on the Rondout; (3) that the cost of developing the Schoharie watershed is less than the cost of developing any other available source; (4) that the development of the Schoharie will complete the Catskill mountain supply as authorized.

Amended Schoharie plan. On December 22, 1915, the Board of Water Supply submitted a report with amended map, plan and profile, with the dam located at Gilboa, to the Board of Estimate and Apportionment, which after due advertisement in all counties, by or through which water from Schoharie creek naturally flows, which included all those bordering the Schoharie creek, the Mohawk and Hudson rivers, held public hearings and approved the project on January 31, 1916. A petition was immediately submitted to the State Conservation Commission. On due advertisement in all counties affected, hearings were held by it. In moving the dam-site down stream, the land for the reservoir site was located in two counties in addition to those specified in the Statute, Chapter 724 and 725 of the Laws of 1905, wherein special provisions for damages to lands and businesses not taken are allowed. Thus it was necessary to go to the Legislature before the Conservation Commission could certify that the plans were just and equitable to the civil divisions of the State. With these provisions of the statute corrected, the Conservation Commission approved the amended project on June 6, 1916.

Preliminary work. The land-taking surveys were begun in July, 1916, and detailed sub-surface investigations by borings for the tunnel location and for the dam foundation were prosecuted in 1916

and 1917. This work was at first concentrated on the tunnel, as it will take longer to construct than to build the dam. There were 16,800 linear feet of borings made in definitely fixing the tunnel line, grade and shaft sites, while an additional 8,400 linear feet of borings were made at the Gilboa dam site, these together totaling 4.8 miles in addition to the preliminary borings previously mentioned. The agreement prices of these borings ranged from $2.25 to $3.00 per linear foot, the average price being $2.50.

The property has been acquired by condemnation as provided by the special act under which the Board is operating. There is a provision by which title becomes vested in the City at the time the commissioners of appraisal file their oaths of office and upon the City paying one-half the assessed valuation. The City became vested with the real estate, 80 acres fee, 49 acres easement, total 129 acres for the tunnel and shaft sites, on May 25, 1917, and that for the reservoir, 2372 acres fee with 2 acres road easements, on November 24, 1917; aggregating 2503 acres. The preliminary work of definite location and surveying, mapping and formalities of securing the property thus consumed about a year and a half from the date of the final approval of the project.

The Gilboa dam. Contract 203, for the Gilboa dam and appurtenances, was awarded on June 23, 1919, to the Hugh Nawn Contracting Company, Roxbury, Mass., the amount based upon contract quantities and unit prices being $6,819,910. The dam will be located in the town of Gilboa, Schoharie County, about four miles northeast of the Grand Gorge station of the Ulster & Delaware railroad. This is 66 miles by rail from Kingston and 155 from New York.

The dam will be of two distinct types. On the east side of Schoharie creek and in the bottom to the stream the rock is at or near the surface; on this rock foundation will be constructed an overfall masonry portion 1300 feet long and 160 feet high. The west bank is composed of a very stiff impervious clay, which extends in every direction, and the preglacial gorge of the stream is completely filled and deeply covered with tight and impervious material; for this side of the stream an earth embankment portion 1000 feet long and approximately the same height as the masonry portion will be built. At the transition section the dam will be flanked both upstream and downstream by a heavy masonry retaining wall to intercept the long slopes of the earth section.

The overfall section is designed with steps on the downstream side

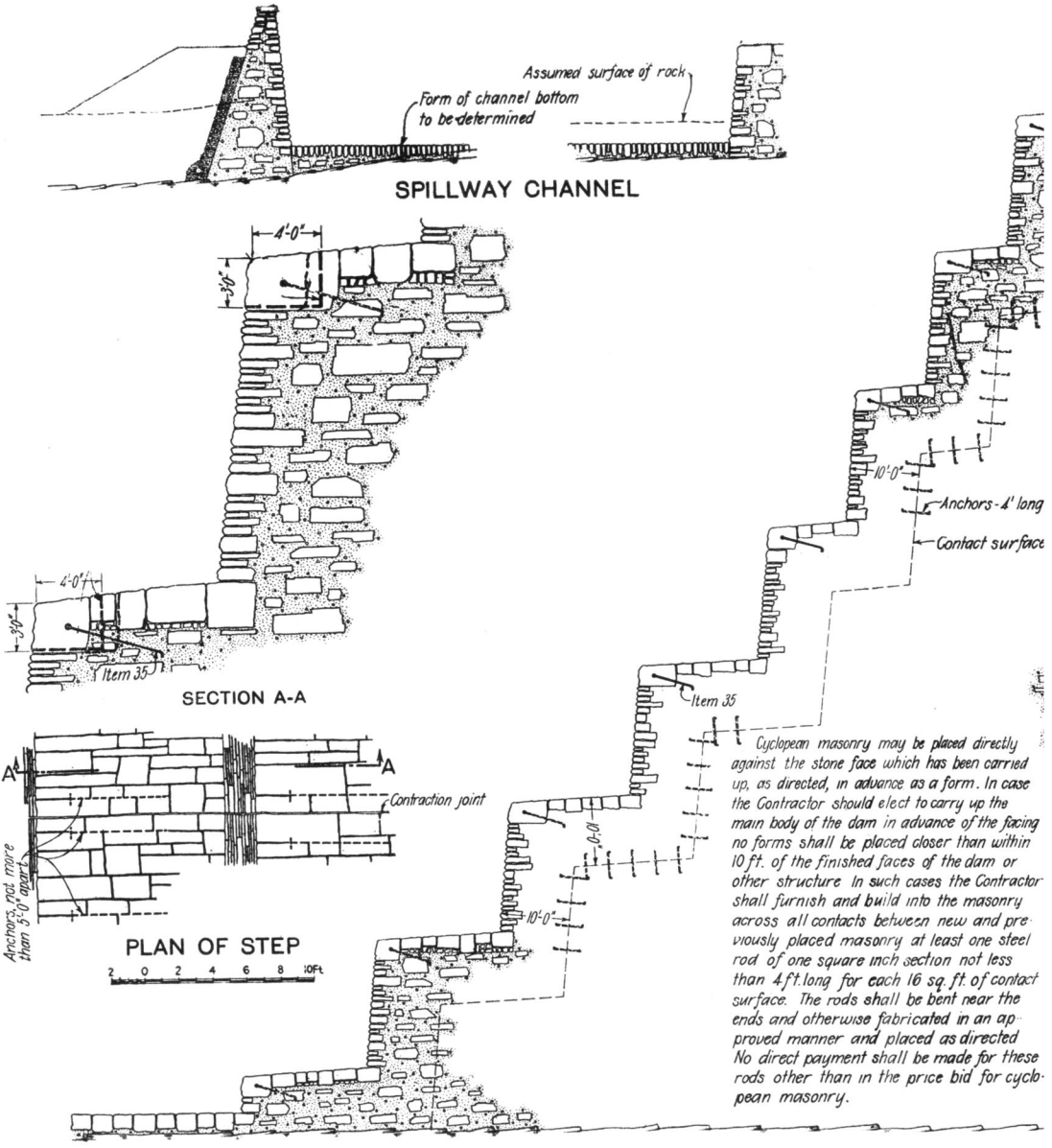
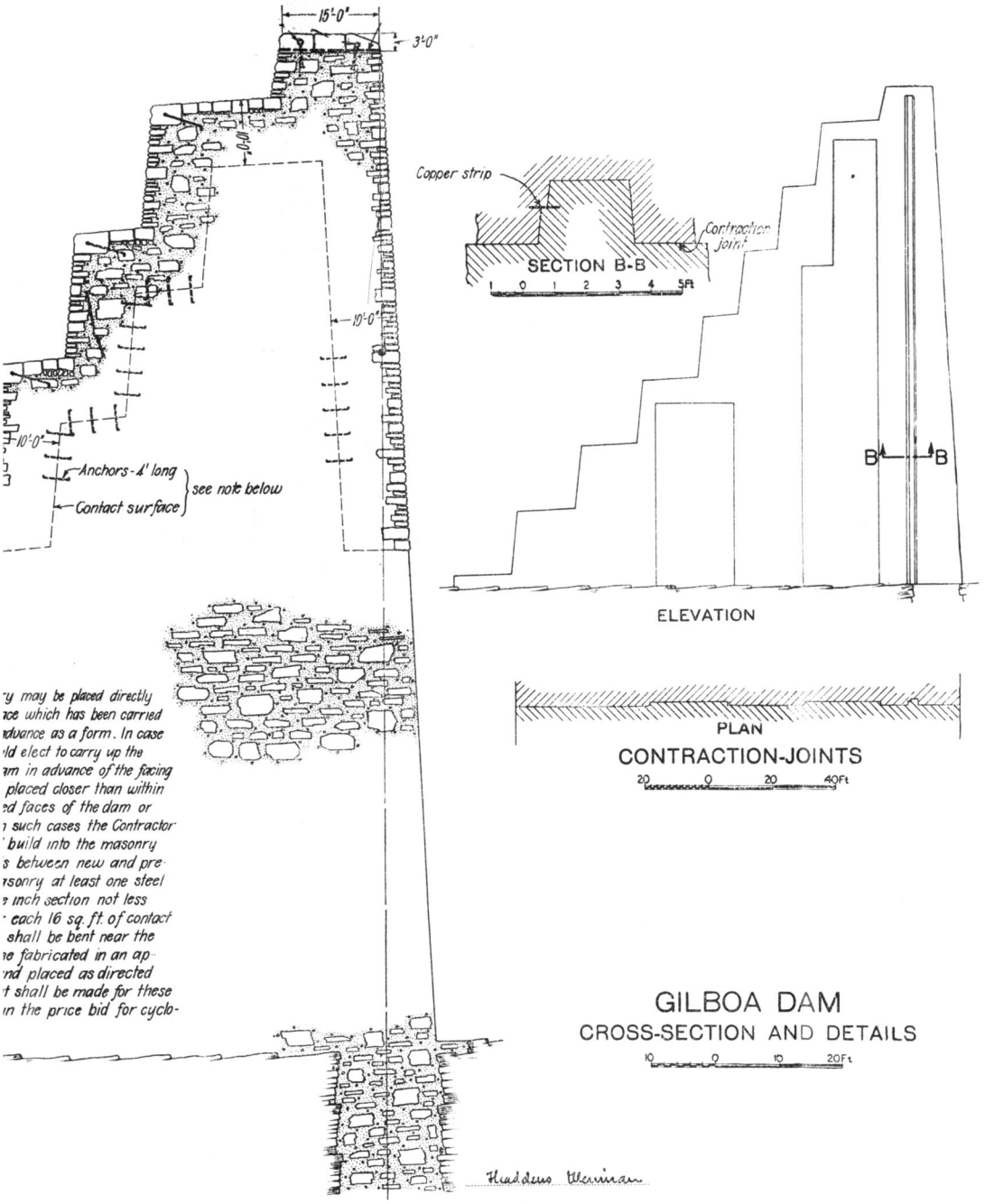


FIG. 4. SECTIONS OF THE GILBOA DAM AI



HE GILBOA DAM AND SPILLWAY CHANNEL

for the purpose of breaking up and safely conducting the overflowing water down the face of the dam to the spillway channel below. All the masonry will be concrete into which stones may be imbedded in the sizes and proportions found practicable. All exposed surfaces are to be of selected native sandstone with mortar joints. The earth portion of the dam is of conventional design with masonry corewall and with heavy rock paving on the upstream slope.

The spillway channel, along the toe of the dam, which will discharge waste waters into Schoharie creek below, is about 80 feet wide at the upper end and 300 feet at the lower; the rock bottom slopes rather steeply and will be protected where necessary with masonry and substantial paving. The side of the channel away from the dam will be defined by a masonry retaining wall. A field model of the overfall section and the spillway channel is now being constructed by the engineers to determine certain details necessary to properly control the overflow.

The contract includes also the construction of about three miles of highways which must be completed before active operations on the dam can begin.

The stream control scheme during construction outlined in the contract is similar to that used at Ashokan dam, involving the placing of first, two large steel pipes over the foundation cut-off trench and later the construction of an arched opening through the dam, 45 feet wide by 50 feet high, which will be filled with concrete when the dam is completed. There is also a permanent blow-off with 30-inch valve in duplicate. The principal items of the contract are 396,000 cubic yards of earth excavation, 92,500 cubic yards of rock excavation, 617,000 cubic yards of refilling and embanking, 436,000 cubic yards of masonry and 480,000 barrels of Portland cement. The contract time is 66 months.

The Shandaken tunnel. Contract 200, for the Shandaken tunnel, was awarded November 9, 1917, to The Degnon Contracting Company of New York City for $12,138,738 based on contract quantities and unit prices. As this is an unusually long tunnel it was considered advisable to divide the work into two parts upon which intending bidders might submit their proposals separately; but the low bid accepted for the entire tunnel was less than the sum of the separate part bids received. The main parts of the contract comprise the intake works, the tunnel and the outlet works.

The intake works will be located about 3 miles north of the village of Prattsville and 2 miles south of the dam on the westerly side of the reservoir. They will consist of an intake channel and chamber with superstructure and an intake shaft. The chamber will be built into the rock and will house eight 3- by 7-foot sluice gates set radially in the wall of the central well or extension of the intake shaft. The superstructure will have rubble walls of native bluestone, re-inforced concrete floors, steel roof trusses and steel framing for the crane over the intake shaft. This building will have two wings, providing living quarters, garage, office, machine shop and store rooms. The intake shaft will be 14 feet in diameter, except where constricted near the top by a Venturi meter.

The tunnel extending from the intake works in a general southeasterly direction for a distance of 18 miles to the outlet works, to be located on the upper reaches of the Esopus creek just south of the village of Allaben, will be of sufficient size and gradient to transport water from Schoharie reservoir to the upper reaches of Esopus creek at the rate of 600,000,000 gallons a day. The velocity of the flowing water will be 8.7 feet per second, equals 5.9 miles per hour, acting as a grade tunnel. The tunnel will be operated intermittently at varying rates, depending on the conditions of stream-flow and storage. The intake sill will be at elevation 1050 and the outlet channel weir will be at elevation 969. The tunnel will be in shale or sandstone, except for about 350 feet of tunnel in earth adjoining the outlet, and will be lined throughout with concrete.

The waterway section is of horseshoe shape, 11 feet 6 inches high by 10 feet 3 inches wide, inside dimensions, about 5.7 cubic yards of excavation per linear foot, and the tunnel will have a uniform grade of 4.4 feet per mile except for the northerly 3½ miles, which will be depressed in order to pass in rock of good quality beneath the gorge of the Bear Kill.

There are seven intermediate shafts, which will be permanent in order to provide ready access to the tunnel. The shafts will be lined with concrete and will have a diameter of 14 feet inside. Small superstructures of native stone will cap each shaft and guarded openings in the floor and walls of these buildings will provide for air movements in the tunnel. The aggregate depth of shafts will be 3,238 linear feet, the maximum depth of a single shaft being 630 feet. The minimum distance between shafts is 1.3 miles, the maximum 2.7 miles.

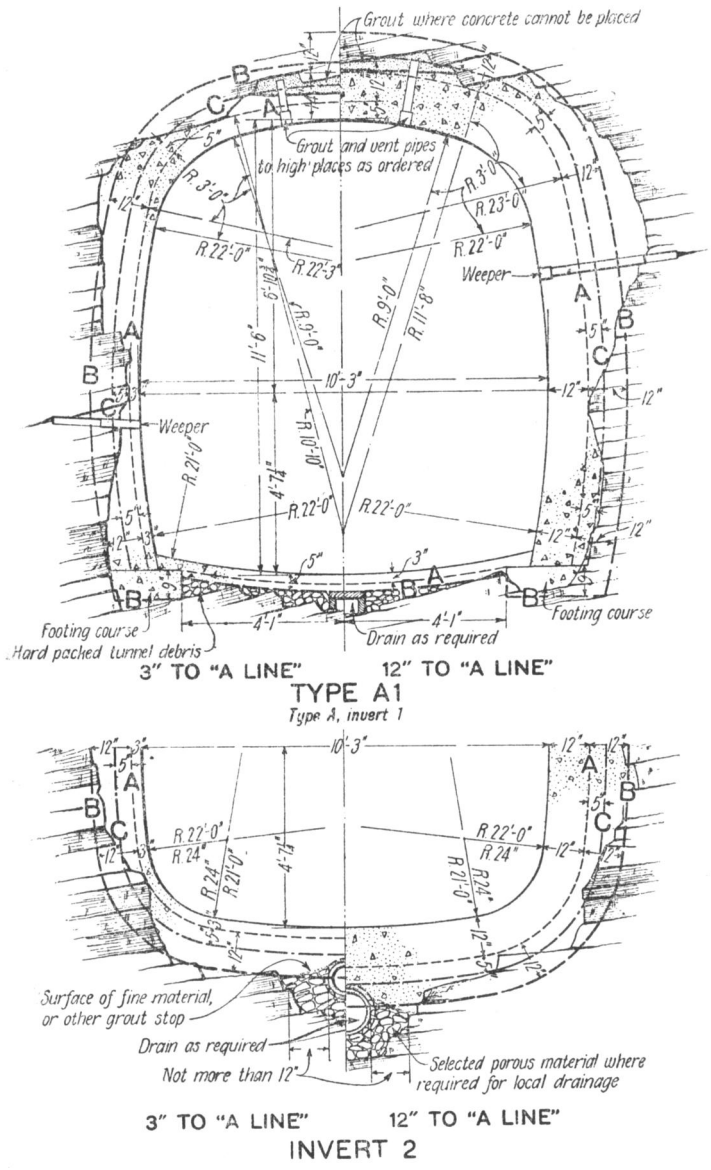


FIG. 5. SECTION OF SHANDAKEN TUNNEL

Invert 2 may be substituted for Invert 1 with any type of tunnel in rock

Work has been going on since the award of the contract and to July 16, 1919, about 2800 linear feet or 86 per cent of the total depth of shafts has been excavated and 2,560 linear feet or 79 per cent of the aggregate depth of shafts lined with concrete, the lining being placed in stretches following the excavation. Three of the shafts have reached tunnel grade and the others, except the intake shaft, are nearing it. The maximum weekly progress of shaft excavation in each of the seven shafts has been between 27 and 42 linear feet, and the average progress of all shafts 12 feet per week.

The outlet works at Allaben on Esopus creek will be located 11 miles above the Ashokan reservoir or 16 miles above the Ashokan dam. They will consist of about 500 feet of aqueduct of the cut-and-cover type, an outlet chamber and about 290 feet of open outlet channel. The cut-and-cover aqueduct will be of horseshoe shape, 11 feet 6 inches high by 10 feet 3 inches wide. Near the lower end it becomes a reinforced concrete waterway 11 feet 6 inches in diameter, with a fall of 16½ feet, providing a water seal for the tunnel outlet. The outlet chamber will be an open flaring structure, whose invert will slope upward to the invert, elevation 969, of the open channel. The latter willl have masonry side-walls and local stone paving. Sloping gently for 290 feet and passing under a steel girder bridge, which will carry the highway, the channel will discharge the water from the tunnel into Esopus creek on its way to Ashokan reservoir.

The estimated contract quantities are about 600,000 cubic yards of rock excavation, 100,000 cubic yards of earth excavation, 200,000 cubic yards of concrete masonry and 445,000 barrels of Portland cement. The contract provides direct payment for medical services for the laborers and sanitary services for the camps and working locations. The shaft work has been done with individual plants at each location, but a power line is being constructed by the contractor to bring electric energy from Kingston for the tunnel work. Within 78 calendar months the work underground must be completed so that the tunnel can be operated, and all work must be completed within 7 years.

Highways and miscellaneous. Contract 202 for the grading of about 7¾ miles of highways around the Schoharie reservoir, was awarded on June 13, 1919, to the Schunnemunk Construction Company, Highland Mills, N. Y., for $176,700, based on the contract quantities and unit prices. The estimated quantities are 112,500

cubic yards of earth and rock excavation, 7,550 cubic yards of paving, masonry, etc., 6,500 barrels Portland cement and 22,000 linear feet of wooden guard rail. The contract time is 18 months.

Other Schoharie work not yet under contract will be a permanent highway bridge over Schoharie creek below the dam, a highway bridge and approaches over the Manorkill, a tributary of the reservoir, and the clearing of the reservoir site. To finish the main aqueduct to the City, additional tubes at 14 locations of steel-pipe siphons will be required.